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QUARTERLY PROGRESS REPORT

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Bellcomm

QUARTERLY PROGRESS REPORT

July August September

1969

I. M. Ross
President

Bellcomm
955 L'Enfant Plaza North, S. W. Washington, D. C. 20024

Report No. 69-101-4
Contract NASW-417

QUARTERLY PROGRESS REPORT

ABSTRACT

The activities of Bellcomm during the quarter ending September 30, 1969 are summarized. Reference is made to reports and memoranda issued during this period covering particular technical studies.

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Table of Contents Page

APOLLO/SATURN SYSTEMS ENGINEERING	1
Mission Planning	1
Performance and Design Requirements	6
Scientific Studies	13
APOLLO APPLICATIONS SYSTEMS ENGINEERING	18
ADVANCED MANNED MISSIONS SYSTEMS ENGINEERING	28
MISSION OPERATIONS STUDIES	33
SPECIAL TASK ENGINEERING STUDIES	34
Manned Space Flight Experiments Program Studies, Task Order No. 34	34
Analysis of Haze Effects on Martian Surface Imagery, Task Order No. 35	36
GENERAL MISSION ENGINEERING STUDIES	37
ENGINEERING SUPPORT	42
ADMINISTRATIVE	43
LIST OF REPORTS AND MEMORANDA	44

APOLLO/SATURN SYSTEMS ENGINEERING
MISSION PLANNING

Mission Assignments

A revised issue of the Apollo Flight Mission Assignments document was approved in July and subsequently published by NASA. This issue identified six additional lunar landing missions (Apollo 15 through Apollo 20) and established weight requirements for science payloads. The concept of descent orbit insertion of the LM by the CSM was introduced for the first time. A separate chart was added to summarize the experiments and cameras assigned to each flight.

Apollo Program Directive No. 53 was prepared for and subsequently released by the Apollo Program Office. This directive deleted lunar landing sites Nos. 2 and 3 from consideration for Apollo 12, thus identifying site 7 as the prime landing site, and established that two launch windows per month would be planned for that mission.

The existing post-flight reporting procedures were reviewed for their completeness and adequacy in assessing the results obtained from Principal Detailed Objectives.[1] Areas for improvement in reporting procedures were suggested. A letter was prepared for the Apollo Program Director directing the Centers to prepare assessment reports for each of the Detailed Objectives that support the Primary Objectives on each flight.

A new issue of the Apollo Flight Mission Assignments document was prepared in draft form. This draft was ready for coordination with the Centers at the end of the quarter. It contains controlled Detailed Objectives for mission H-1, appendixes for each mission through J-5, and a set of ΔV requirements for the H missions.

Technical activities related to Apollo 12 included review of the Preliminary Flight Rules and Preliminary Flight Plan. A flight test of the Landing Point Designator (LPD) on Apollo 12 was proposed as a means of developing a point landing capability without excessive ΔV penalty or crew risk.[2] It was found that such a flight test was possible although the requirement to land near

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(1) Reporting Procedures for Detailed Objectives, Memorandum for File, H. F. Connor, September 22, 1969.

(2) Flight Test of the LM Landing Point Designator, Memorandum for File, A. C. Merritt, July 17, 1969.

Surveyor III on Apollo 12 should insure the use of the LPD without a specific flight test objective. Recommendations were made for further analysis of point landing development.

Vehicle Performance

Monthly preparation and delivery of Weight and Performance Reports, as well as presentation of weight and performance status at Apollo Program Office Reviews, continued. Some changes were made to the method used for propellant calculations for weight and performance reporting to reflect statistical combination of independent dispersions.

Changes to weight and performance criteria for missions H and J are being coordinated with the Centers for possible use in a revision to the Apollo Program Specification.

Mission Analysis

Development was initiated of hybrid trajectory lunar accessibility programs to bound the regions of the moon which can be considered for lunar exploration missions. Preliminary accessibility plots have been obtained.

A study was begun to determine accessibility to Tycho using three-impulse deboost with LM Descent Propulsion System (DPS) abort capability. Preliminary results indicate that this profile may reduce the ΔV required for lunar orbit insertion by approximately 200 fps in comparison to a single-impulse deboost trajectory.

Studies related to multiple impulse trajectories have developed a new technique for trajectory optimization, which has been incorporated in the three-impulse computation programs.[3] Also, a rapid computation technique has been developed for use in three-impulse orbital departure analyses to define fuel optimum injection from eliptical orbits to a specified velocity vector at "infinity." Work has been started to incorporate the constraint for LM DPS abort capability into the trajectory program for a three-impulse deboost.

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(3) A Method for Determining Minimum ΔV Two Impulse Transfer Trajectories Between Arbitrary State Vectors and Its Application to Three Impulse LOI Optimization, Memorandum for File, R. A. Bass, E. A. McGinness, September 24, 1969.

A study was done of communication visibility of the landing site during the Apollo 12 mission for antennas at Goldstone, Parkes, and Jodrell Bank.[4] The times during which communications could be maintained were determined for each antenna site.

Tradeoffs between LM landing accuracy and redesignation ΔV, using the LM landing point designator, were made.[5] It was shown that significant savings in the ΔV requirement result if a circular target area rather than a point target is acceptable. Included in the study was a determination of the optimum aim point for various error ellipses and target areas.

Guidance and Navigation

A study was made to evaluate the ΔV cost of redesignation during the LM powered descent phase.[6] The ΔV cost was found to be ten fps or less per nm of redesignation, for up to three nm redesignation. A LM descent trajectory having a steeper (28°) approach path is being studied for possible improvement in surface visibility and site redesignation capability.

An analysis of Apollo 10 tracking data showed that small thrusting, of magnitudes not normally measured by the spacecraft, can impair the accuracy of navigation in lunar orbit.[7] These thrustings result from such things as RCS single jet attitude maneuvers and waste water dumps.

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(4) Mission H1 Landing Site Visibility by Goldstone, Parkes and Jodrell Bank, Memorandum for File, R. A. Bass, August 14, 1969.

(5) Use of the Landing Point Designator to Land the Lunar Module in a Circular Target Area, Memorandum for File, K. P. Klaasen, September 16, 1969.

(6) ΔV Cost of Updating the Landing Site During the LM Descent Braking Phase, Memorandum for File, F. LaPiana, P. A. Whitlock, August 21, 1969.

(7) An Analysis of Apollo 10 Tracking Data Utilizing the POLAR Version of the Osculating Lunar Elements Program, TM-69-2014-9, M. V. Bullock, A. J. Ferrari, September 30, 1969.

Methods for the determination of lunar mascon size and location from lunar orbital velocity data were studied.[8] The ability to simulate lunar mascons was added to the Bellcomm BCMTAP computer program.[9]

Previously reported work on the use of osculating orbital elements for orbital determination and prediction was documented.[10] The validity of this method was checked using Apollo 8 tracking data.[11]

To improve the lunar gravity model, it was suggested that tracking data from the lunar far side could be obtained using a two-satellite system with one satellite in high orbit to relay tracking data from the second satellite. This method does not require landmark sightings on the moon and thus does not require a manned spacecraft.

The common navigational stars and planets which will be visible in the LM Alignment Optical Telescope during the lunar surface portion of the Apollo 12 mission were determined as a validation of MSC star calculation programs.[12] Apollo landing sites Nos. 5 and 7 for the November and December 1969 opportunities were considered.

Two versions of a Star Finder and Identifier for a lunar surface observer were developed.[13] These devices display the apparent azimuth and elevation

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(8) A Study of Methods for Determining the Location and Magnitude of Lunar Mass Concentrations, Memorandum for File, M. Lybanon, R. M. Scott, July 30, 1969.

(9) Addition of "Mascons" in BCMTAP and a Preliminary Analysis of their Effects on Orbit Determination, Memorandum for File, J. T. Findlay, July 31, 1969.

(10) Representation of Osculating Orbital Elements by Analytic Functions, Memorandum for File, M. Lybanon, R. M. Scott, September 30, 1969.

(11) Propagation Characteristics of Apollo 8 L.P.O. Solutions Obtained from the Osculating Lunar Elements Program, Memorandum for File, M. V. Bullock, A. J. Ferrari, September 30, 1969.

(12) Stars and Planets Visible in the LM AOT During the Lunar Stay Time of the Apollo 12 Mission, Memorandum for File, T. L. Yang, September 29, 1969.

(13) A Star Finder and Identifier for Use on the Surface of the Moon, Memorandum for File, D. A. Corey, September 2, 1969.

of stars and planets, given an estimate of the observer's position and the time of the observation. One version is similar to an existing device familiar to earth-based navigators, while the other version is a new device featuring easier readability for an observer located near the equator.

The final report on the Entry Monitoring System Study was issued.(14) Work by the Bell Telephone Laboratories on a different form of entry guidance logic for Apollo-type vehicles was completed.(15, 16,)

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(14) Entry Monitoring System Study, TR-69-310-1, I. Bogner, G. Duncan, C. H. Eley, III, D. S. Lopez, S. B. Watson, September 26, 1969.

(15) Predictive Entry Guidance for Apollo. Part 1: Design and Performance, MM-9-4162-2, J. A. Stiles, G. Bamesberger, Bell Telephone Laboratories, July 21, 1969.

(16) Predictive Entry Guidance for Apollo. Part 2: Structure and Operation, MM-9-4162-3, J. A. Stiles, G. Bamesberger, Bell Telephone Laboratories, July 21, 1969.

APOLLO/SATURN SYSTEMS ENGINEERING PERFORMANCE AND DESIGN REQUIREMENTS

Apollo Program Specification

Revision of the Apollo Program Specification is in process to incorporate approved changes for the lunar exploration program.

Communication Systems

A study was made of lunar surface communication using frequencies between 100 kHz and 10 MHz for an over-the-horizon voice circuit.(17) It was found that a range of five kilometers could be achieved using a transmitter power of 250 milliwatts in conjunction with a 15 meter monopole antenna. While the required transmitter power is small, the antenna size is undesirably large. Terrain irregularities such as craters and hills which intercept the transmission path could substantially modify the assumed propagation attenuation, and empirical data is needed to improve the estimates of propagation loss for such situations.

An analysis was made of the performance margins expected for communication between a Manned Space Flight Network (MSFN) station with an 85 foot diameter antenna and a Lunar Module in lunar orbit using its omnidirectional antenna.(18) It was shown that satisfactory margins would exist for low bit rate telemetry, baseband backup voice and ranging, and that inadequate margin was available for high bit rate telemetry. The use of the LM omnidirectional antenna is a contingency operating mode in event of failure of the steerable antenna.

Techniques were derived for specifying optimum and near optimum linear phase locked loop FM receivers to demodulate frequency modulated signals (such as used in the unified S-Band system).(19) A near-optimum demodulator could

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(17) Required Transmitter Power for Ground Wave Radio Propagation Beyond the Lunar Horizon in the 100 kHz to 10 MHz Frequency Band, Memorandum for File, K.H. Schmid, July 23, 1969.

(18) Performance at Lunar Range of a Unified S-Band PM Communication Link Between an MSFN Station With an 85 ft. Antenna and a LM Using an Omni Antenna, Memorandum for File, N.W. Schroeder, August 6, 1969.

(19) Optimum and Suboptimum Demodulators for FM Signals With Multiple Subcarriers, TM-69-2034-7, W.D. Wynn, August 11, 1969.

yield a ten db improvement in threshold for certain Apollo USB modes, such as data and voice dumps, as a consequence of filtering out broadband noise in the passband of the present phase-locked loop. For some other modes, including television, little improvement is to be expected. The filters associated with these demodulators are derived by solving the classic Wiener-Hopf integral equations. When the signal to be filtered has a spectrum that is a rational function of frequency, the derivation of the optimum filter is straightforward. Some spectra, such as the telemetry channel in the Apollo System, do not satisfy this criteria and to derive a near optimum filter is a difficult and tedious numerical problem. A computer method was developed for deriving a rational approximation of the Apollo USB telemetry signal spectrum.[20] This method can provide a good approximation of the desired spectrum in a more concise form than methods used previously.

An analysis was completed which shows that it is technically feasible to provide limited communication between earth and an astronaut on the lunar surface, using the existing extravehicular communications backpack system and an earth-based VHF station with a one kilowatt transmitter and a 60 foot diameter antenna.[21] This system would permit transmission of VHF-AM voice to the astronaut and reception of a VHF key mode from the astronaut. Little change to the existing backpack would be required, and the system could provide backup to normal communication or a minimal direct-to-earth link during EVA.

Launch Systems

A review was made of the evolution of safety factor criteria for pressure vessels used in space flight systems. A draft specification intended to unify terminology and practices has been prepared and is being discussed with the Centers.

Project Pyro was an experimental program designed to obtain data useful for assessing the hazards from liquid propellant rocket explosions. Bellcomm was requested by KSC to perform a critique of the results of this program. As

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(20) A Computer Method for the Determination of Rational Functions, TM-69-1033-4, S.Y. Lee, September 10, 1969.

(21) A Possible VHF Backup Communications System Between Extravehicular Astronauts on the Lunar Surface and the Earth, Memorandum for File, R. L. Selden, September 19, 1969.

part of this critique the Project Pyro data was statistically analyzed to determine the dependence of TNT equivalent yield on weight; this involved developing techniques for estimating yields and analyzing the departures from TNT blast behavior.(22) Except for one case where the test data was anomalous, the Bellcomm analysis indicated a definite fall-off of yield with increasing weight for both the LO_2/LH_2 and LO_2/RP-1 propellants. This differed from the predictions in the Project Pyro final report of constant maximum yield independent of weight.

A summary of present plans for checkout of space vehicles at KSC for Apollo lunar exploration missions was prepared.(23) Requirements for servicing the expanded cryogenic storage system of the CSM for lunar exploration were reviewed.(24) Design options were identified to obtain flexibility and high reliability without increasing the servicing timeline.

Recent developments in planning of space vehicle turnaround operations in event of a launch scrub for lunar exploration missions were summarized.(25) A presentation on Apollo 12 Scrub-Turnaround planning was made to the Apollo Program Office.

An assessment was made of the CSM LH_2 quantity red-line negative margin on the Apollo 12 Mission.(26) Candidate improvements submitted by the Centers were evaluated. It was concluded that a positive margin could be realized for Apollo 12, but launch delays, scrub-turnarounds, and the requirements of future longer duration H missions remain as potential problems.

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(22) Statistical Analysis of Project Pyro Liquid Propellant Explosion Data, TM-69-1033-3, P. Gunther, G.R. Andersen, July 23, 1969.

(23) ALEM Checkout at KSC, Memorandum for File, C.H. Eley, III, July 24, 1969.

(24) Preliminary Thoughts on Cryogenic Servicing of the 16-day CSM, Memorandum for File, G. J. McPherson, Jr., August 11, 1969.

(25) Recent Developments in Space Vehicle Turnaround Operations for Lunar Missions, Memorandum for File, C.H. Eley, III, August 6, 1969.

(26) CSM LH_2 Quantity Redline Negative Margin on the Apollo 12 Mission, Memorandum for File, G.J. McPherson, Jr., September 18, 1969.

Lunar Exploration Design Requirements

Work continued on the definition of both systems and overall requirements for lunar exploration. An analysis was completed which compared the metabolic capabilities (4800 and 6400 Btu) of two candidate life support systems for lunar exploration with the metabolic usage envelope of an astronaut.[27] Using fatigue considerations as an index to man's capabilities, it was concluded that only the larger system had sufficient capacity to assure that the overall operational capability would be limited by the man rather than the life support system. The fatigue and no-fatigue limits defined in the study have been adopted for use in lunar traverse planning. A study of the life support systems identified a possible deficiency in the carbon dioxide removal capability of the primary life support system. This was reviewed with MSC and was found to justify a restatement of the metabolic capacity of the -7 PLSS as 6000 Btu.[28]

Analyses were made to characterize the overall operational capability envelope for lunar exploration as defined by the man, the mobility mode, and the extravehicular system. A parametric study was completed of the use of mobility aids including walking during lunar exploration traverses. The purpose was to understand the relationships between mobility mode and the time available for science.[29] Using a fixed metabolic capacity for life support systems, the study showed that for small site separations ($<$1 km), high riding speeds (10-15 km/hr) are required to effect a significant improvement in time-at-site over that obtained with reasonable walking speeds. Further, set-up-time and ingress/egress time can easily offset any gain in time-at-site afforded by the mobility aid. The study results were also used to define the maximum useful range for rover design requirements. Another study showed that the maximum radius of operation from the LM in riding missions could be increased by an order of magnitude by providing an improved backup life support system. Test results from one-g and one-sixth-g simulations were analyzed, and agreement was

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(27) EVA Metabolic Capacity Required for LEP Life Support Systems, Memorandum for File, T.A. Bottomley, August 11, 1969.

(28) Review of Portable Life Support System Capabilities for LEP, Memorandum for File, T. A. Bottomley, August 19, 1969.

(29) Further Results of Tradeoffs Between Walking and the Use of Mobility Aids During Lunar Surface EVA, Memorandum for File, P. Benjamin, July 14, 1969.

reached with MSC on metabolic rates to be used in planning of lunar surface traverses. Baseline rates and derating factors for weight carrying, terrain effects, and obstacle avoidance were defined for all mobility modes and for science activities.(30) The operational capability envelopes were developed in nomograph and chart form to permit rapid evaluation of the feasibility of proposed traverses, and were made available to NASA.

Studies were made to develop preliminary exploration traverses which satisfied specific science objectives and were consistent with predicted operational capabilities.(31) The results demonstrated the value of mobility aids and extensions of life support systems in increasing traverse length and time available at the stop-off points. More detailed comparisons of science return for several mobility modes were made for three J-mission sites for which high resolution photography was available. These studies showed that a rover would essentially double the science time, and would significantly reduce the degradation of science return associated with large changes in LM landing point location. They also showed that a five-hour limitation on allowable time in a pressurized space suit is the controlling constraint on surface operational capability for riding missions.

A preliminary analysis was made of a scheme for using a combination of CSM photography and lunar surface markers to provide postflight positional information on lunar surface operations.(32) It was concluded that markers with areas of one to four square yards could be resolved in photographs taken at orbital altitudes of 40 to 60 nm.

Space Vehicle Systems

Studies were conducted to evaluate lunar exploration hardware systems' options in the LM, CSM, Extravehicular Mobility Unit (EMU), and Lunar Roving Vehicle (LRV) areas. Hardware alternatives and decision issues were summarized for the Apollo Program Office in a presentation on September 2.

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(30) Definition of Energy Costs for Lunar Surface EVA, Memorandum for File, T.A. Bottomley, September 8, 1969.

(31) Engineering Implications of Preliminary Scientific Traverses for the Apollo J Missions, Memorandum for File, P.F. Sennewald, August 25, 1969.

(32) LEP Post Traverse Location of Scientific Sites Using CSM Photography, Memorandum for File, D.M. Duty, July 14, 1969.

Structural safety factors of the Saturn V vehicle for lunar exploration payload changes are being reviewed. Present data indicate that proposed payload and acceleration increases may result in marginal safety factors at several stage interfaces.

A review was made of the accuracy with which consumables usage had been predicted in the Apollo missions to date. The findings were presented to the Apollo Program Office.[33] They showed high accuracy for the dominant consumable systems and improvement with experience.

Work has been started to analyze fuel sloshing in the LM. Slosh models used by MSC and MIT/IL have been obtained and are being studied.

Effort was continued on several aspects of space vehicle structural and dynamic modeling. Refinement of S-II structural data has produced good agreement with many features of the SA-503 S-II flight data in frequency, phase and amplitude.[34] Many questions about the suction line and engine transfer functions were resolved after close interchange with both MSFC and Rocketdyne. The new structural model together with the suction line and engine transfer functions yields stability predictions that are close to the flight results. However, one more iteration seems necessary to attain the fidelity of the model necessary to allow a meaningful evaluation of an accumulator for the S-II POGO fix.

A program capable of analyzing axisymmetric shells was completed.[35] This program will provide finite element stiffness properties for axisymmetric shells including both membrane and bending effects. It was generated in support of tank-fluid response studies being conducted in an effort to explain the observed S-II flight data.

An evaluation of a multi-degree-of-freedom axial model of a loaded propellant tank is continuing. Finite element model results are being compared to more exact continuum model solutions, with very poor correlation to date.

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(33) APO Briefing September 24, 1969, Precision of Consumables Estimates for Apollo, Memorandum for File, S.S. Fineblum, September 24, 1969.

(34) Updated S-II Longitudinal Structural Model, Memorandum for File, H.E. Stephens, July 18, 1969.

(35) Axisymmetric Shells, TM-69-2031-3, S. Kaufman, July 24, 1969.

A study of the determination of dynamic loads using statistical techniques was completed.(36) It is applicable for purely random loading functions, such as random thrust oscillations. A method of determining the probable occurrence of peak loads, mean loads and standard deviations was derived.

A modal synthesis technique has been completed and programmed.(37) This technique provides means of performing modal analysis of very large degree-of-freedom structures without exceeding the capability of eigensolution routines. A routine to determine eigenvalues and orthogonal eigenvectors for repeated roots was completed and incorporated in operational modal analysis programs.(38)

Data obtained from spectrum analyses of a number of Apollo 10 S-IVB and command module measurements during the preceding quarter were summarized and distributed.(39)

At the request of the Apollo Mission Director, an assessment was made of documentation, configuration control, and design of the emergency detection system of the Saturn V. It was concluded that certain shortcomings exist but are compensated by other system features.

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(36) Determination of Dynamic Loads and Response of a Space Vehicle Using Flight Data, TM-69-2031-4, S. N. Hou, August 14, 1969.

(37) Review of Modal Synthesis Techniques and a New Approach, TM-69-2031-5, S. N. Hou, September 26, 1969.

(38) Eigenvalues and Eigenvectors of Symmetric Matrices, Memorandum for File, J. S. Vandergraft, July 31, 1969.

(39) Spectrum Analyses of Apollo 10 S-IVB First And Second Burn, Memorandum for File, A. T. Ackerman, L. A. Ferrara, July 9, 1969.

APOLLO/SATURN SYSTEMS ENGINEERING
SCIENTIFIC STUDIES

Site Selection

At the July 10 Apollo Site Selection Board Meeting, Bellcomm presented a report on the sites recommended by the Group for Lunar Exploration Planning (GLEP) Site Selection Subgroup. A summary was given of recent telescopic observations bearing on differences among proposed Apollo landing sites.(40,41)

The minutes of the June meeting of the GLEP Site Selection Subgroup were prepared and published.(42)

A description was prepared of the characteristics of the ten lunar exploration sites recommended by the GLEP Site Selection Subgroup including the coordinates of the landing point in each site.(43)

A GLEP conclusion that the Hadley/Apennines site is more desirable than Rim Prinz I for information leading to the origin of sinuous rilles was documented.(44)

Bellcomm participated in an Ad Hoc Working Group on Science Objectives for Apollo Missions 12-20. The science objectives, tentative designs, and

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(40) Differences Between Proposed Apollo Sites: 1. Synthesis, Paper published in "Journal of Geophysical Research," Volume 74, No. 17, A.F.H. Goetz (Bellcomm) and H.H. Kieffer, T.B. McCord, B.V. Murray (California Institute of Technology), August 15, 1969.

(41) Differences Between Proposed Apollo Sites: 3. Far Infrared Emissivity Evidence, Paper published in "Journal of Geophysical Research," Volume 74, No. 17, A.F.H. Goetz (Bellcomm), L. A. Soderblom (California Institute of Technology), August 15, 1969.

(42) GLEP Site Selection Subgroup, Fourth Meeting, June 17, 1969, Memorandum for File, N.W. Hinners, August 4, 1969.

(43) Characteristics of the Ten Lunar Exploration Sites, Memorandum for File, F. El-Baz, August 1, 1969.

(44) Some GLEP Recommendations on Lunar Exploration Sites, Memorandum for File, F. El-Baz, September 11, 1969.

tentative designs, and priorities for nine Apollo missions (with emphasis on the last five) were established and presented in the minutes of the meeting.[45]

A presentation on Apollo Lunar Exploration Program Science Objectives and Mission Plans was given to MSC Management on September 4, and to the MSF Management Council on September 9.

Apollo 11

A study was conducted to determine the window for earth-based observatories to range on the Apollo 11 laser retro-reflector for possible acquisition prior to LM lift-off. Acquisition during that period was considered desirable in the event LM lift-off was to cloud the retro-reflector with debris. It was determined that no observatories in the continental United States would be able to perform acquisition during this time if the planned surface timeline was followed.

Data were also prepared to support a proposal for visual sightings of earth-based lasers by the LM crewmen during the period between lunar landing and egress on Apollo 11.

Bellcomm participated in the science teams which supported orbital photography and lunar surface experiments during and after the Apollo 11 mission.

Apollo 12

Recommendations were made for a group of twenty photographic targets for Apollo 12, and for revisions to the target-of-opportunity chart for that mission.

Ground Based Apollo Photography

Nominal pointing angles for the Apollo 11 spacecraft were generated for the professional and amateur astronomers who were providing optical coverage of the spacecraft and its waste water dumps.

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(45) Minutes of the August 12-14 Meeting of an Ad Hoc Working Group on the Science Objectives of Apollo Missions 12-20, Memorandum for File, F. El-Baz, D. B. James, August 18, 1969.

Three papers were presented at an Optical Society of America conference on Optical Contamination in Space. One paper dealt with the effects of leaked contaminants on telescopic observations from spacecraft and on the visibility of such contaminants to ground-based photography.(46) A second paper reviewed work completed to date on the reduction of the Smithsonian Astrophysical Observatory's Baker-Nunn photography of cryogen releases from the S-IVB's on Apollo 8 and Apollo 9.(47) The third paper reported calculations of the lifetime of debris around a spacecraft indicating that, while hydrogen sublimes very quickly, water and oxygen particles do not.

Lunar Science

Work reported earlier on a model for the interaction between the moon and the interplanetary magnetic field has been extended.(48) The model permits determination of the conductivity of the lunar interior based on ALSEP magnetometer data.

Lunar Surface Science

Initial results from the Apollo 11 Dust, Thermal, and Radiation Engineering Measurements experiment (DTREM I) were documented and transmitted to MSC as a draft for possible inclusion in the Apollo 11 Preliminary Science Report. These results included temperature measurements throughout the first lunar day of operation.

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(46) Water and Cryogens in Space: Some Physical Considerations, Memorandum for File, A. C. Buffalano, September 30, 1969.

(47) An Interpretation of Photographic Data Showing S-IVB Cryogen Releases During Apollos 8 and 9, Memorandum for File, A. C. Buffalano, August 29, 1969.

(48) Method for Estimating the Electrical Conductivity of the Lunar Interior, TR-69-103-7-4, W. R. Sill, J. L. Blank, September 22, 1969. Also presented at General Scientific Assembly of the International Association of Geomagnetism and Aeronomy, Madrid, Spain, September 4, 1969.

Hardware and software changes were identified for accurate determination of the S-IVB lunar impact planned for the Apollo 13 mission in connection with seismic investigations. These changes were subsequently approved by the Level I Configuration Control Board. Prime and alternate targeting points were specified for the impact.

Studies continued on lunar surface processes (Orbiter photography interpretation), including a detailed study of the geologic environs of the crater Aristarchus and a related study of the relationship of Aristarchus structures to those surrounding mare basins.

The lunar atmospheric contamination due to an Apollo lunar landing was analyzed.(49) Qualitative results of the study showed that the contaminants are quickly dispersed from the lunar environment and that in less than 72 hours the contaminant density is decreased to more than an order of magnitude below the present estimate of ambient atmospheric density.

A computer program has been written which calculates the total brightness of an ellipsoidal section representing a rimless crater or other such depression. The total brightness and/or contrast is obtained by summing elemental areas. This capability will be used to determine the range at which a particular depression first becomes visible.

Lunar Orbital Science

A rationale for an integrated lunar orbital science program on Apollo 12 through Apollo 20 was developed and presented to the Associate Administrator for Manned Space Flight and to the Manned Space Flight Experiments Board on September 23 and 24. The lunar orbital experiments for this mission series were subsequently approved.

A paper on the proposed data reduction technique for the Lunar Multispectral Photography experiment on Apollo 12 has been submitted for publication.(50) Data reduction for this experiment will be under the direction of the Principal Investigator from Bellcomm.

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(49) Lunar Atmospheric Contamination Due to an Apollo Landing, TM-69-2015-5, G.K. Chang, September 16, 1969.

(50) Color Differentiation by Computer Image Processing, Paper to be published in "Photographic Science and Engineering Journal," A.F.H. Goetz (Bellcomm), F.C. Billingsley and J.N. Lindsley (Jet Propulsion Laboratory).

Reviews and evaluations were conducted of several of the orbital science experiments including the Lyman Alpha Photometer, the Far UV Spectrometer and a Mass Spectrometer. Technical proposals for construction of the X-Ray Spectrometer were evaluated for technical content. Design suggestions were made on the Panoramic Camera.

Pointing requirements and downlink data requirements for the Scientific Instrument Module were reviewed. A recommendation was made to delete the Stellar Reference Camera. It was concluded that the augmented data system scheduled for Apollo 17 will meet the experiment data requirements.

Natural Environment and Physical Standards

The document, "Natural Environment and Physical Standards for the Apollo Program and the Apollo Applications Program", SE 015-001-1B, M-DE 8020.008C, was completed and subsequently published. This publication, which supersedes the "Natural Environment and Physical Standards for the Apollo Program" dated April, 1965, contains revised environmental data and additional models to increase its usefulness to the Apollo Applications Program.

Apollo Lunar Exploration Program Development Plan

Revisions to the lunar exploration science section of the Apollo Lunar Exploration Program Development Plan were prepared to incorporate modified ALSEP and CSM Science.

APOLLO APPLICATIONS SYSTEM ENGINEERING

Mission Assignments

A major revision of the Apollo Applications Flight Mission Assignments document was approved in July and subsequently published by NASA. This issue established a new sequence of missions, objectives, and profiles to reflect the program decision to use the Saturn "dry" Workshop (SWS) with an integral Apollo Telescope Mount (ATM) launched on the first two stages of a Saturn V vehicle instead of the "wet" S-IVB Workshop.

Program Specification

The draft of the Apollo Applications Program Specification which had been revised to provide for the Saturn V launched dry workshop configuration was reviewed by the Level I Configuration Control Board early in August. Comments and recommendations made during the meeting were reflected in the final draft which was subsequently approved by the Program Director and published with an effective date of August 15.

Weight Reporting

AAP Weight and Performance Reports for the dry workshop configuration were given to the Program Director for the months of August and September.

Formal publication has been deferred pending Center submission of weight data for the revised configuration.

Mission Sequence

A Target Site Analysis Program (TSAP) has been developed to graphically display target-site visibility data generated by the Bellcomm Apollo Simulation Program (BCMASP) Earth-Orbit Simulator (EOS).[51] Two general categories of ground targets are recognized by TSAP: MSFN stations (for communications coverage analyses) and photographic targets lying within a field of view calculated by the EOS program. The graphic output of TSAP is helpful in giving a

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(51) TSAP - A Target Site Analysis Program, Memorandum for File, D. P. Nash, September 30, 1969.

rapid identification of those orbits of a mission during which a relatively large or small - number of contact opportunities are found. An option is provided that permits the printing of only those target contacts having a duration greater than a minimum value of interest to the user, as defined in the input data. The alphanumeric designation of each target site encountered, together with the duration of individual contacts and the combined duration of overlapping contacts are indicated.

Development of an in-flight activities scheduling program has been initiated to provide an aid for flight planning studies. Preliminary conceptual design of the input processor and the scheduling algorithm have been completed. Coding of input and scheduling routines is in progress as are conceptual development of output options and the preparation of a data base of activity requirements that affect scheduling opportunities.

Flight Mechanics

Investigations of the guidance, navigation and control performance for the AAP rendezvous missions were continued. The general purpose digital navigation and guidance simulator which has been under development is now producing closed-loop guidance runs. A UNIVAC 1108, FORTRAN V version of the conic subroutines from the Apollo Guidance System Operation Plan (GSOP) has been incorporated into the simulator and tested successfully against MIT simulation results.[52] GSOP routines for calculating the rendezvous maneuvers have also been included, and closed-loop guidance simulation tests with error-free navigation and execution are being made. The CM navigation system is being modeled for subsequent inclusion in the simulator.

The spatial position of a CSM relative to the SWS during the final phase of a typical AAP rendezvous was investigated.[53] This is of interest because the SWS may be held in a solar-oriented inertial attitude during the rendezvous rather than a local vertical orientation as formerly planned with the "wet" workshop. It was determined that in order to provide coverage during the coelliptic orbit and rendezvous terminal phase, the VHF transponder pattern must include an arc of 280° in a plane containing the SWS body X axis and

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(52) UNIVAC 1108 FORTRAN V Version of MIT Conic Subroutines Used in Apollo Guidance Computer, Memorandum for File, C. O. Guffee, J. C. Gurasich, July 10, 1969.

(53) Spatial Orientation of a CSM Relative to a Sun-Oriented SWS during a Typical AAP Rendezvous, Memorandum for File, C. O. Guffee, R. C. Purkey, September 30, 1969.

inclined with respect to the +Z body axis by the beta angle of the sun at the time of rendezvous.

It has been observed that when a propulsion burn is cut off at the Keplerian apsidal velocity, the error in radius at the opposite apside one half orbit later will be between two and ten nm for orbits with inclinations up to 35° and altitudes less than 300 nm.[54] These errors are caused by the asphericity of the earth. An expression has been derived for apsidal velocity which reduces the error to less than 0.1 nm. The magnitude of the correction to be added to the Keplerian velocity depends on the apogee and perigee radii, orbit inclination and the geocentric latitude at which cutoff occurs. The correction is greatest at the lower inclinations and for cutoff at the equatorial crossing. The first three harmonics of the earth's gravitational field are included in the derivation, but only the first harmonic produces a significant contribution.

Electrical Power System Studies

The change to the Saturn V workshop affects the Electrical Power Systems (EPS) previously baselined. Studies have been performed to describe an acceptable total configuration while minimizing the changes to existing designs.

Since the CSM fuel cells will not be available to supply power throughout the mission, some means of load switching or load sharing between the two solar array systems is necessary to meet peak power demands. A design study of a totally integrated system was completed.[55] This design requires slight modification of the ATM solar array modules and substitution of the AM power conditioning groups for the ATM charger-battery-regulator modules to obtain ATM system characteristics identical to the AM. With identical characteristics, the two systems have the capability for parallel operation and can meet all anticipated power requirements.

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(54) A Modified Perigee and Apogee Velocity Expression to Reduce Radius Errors Caused by the Earth's Asphericity, TM-69-1025-1, P. H. Whipple, July 14, 1969.

(55) Electrical Power System for AAP Dry Workshop, Memorandum for File, B. W. Moss, July 29, 1969.

In another study, the operation of the existing AM and ATM systems in a power-sharing mode was analyzed.[56] Particular values of interconnecting cable impedence and no-load voltage settings of the two systems were calculated such that adequate power-sharing at average load conditions would occur. Although this operational mode of the existing systems does not offer the flexibility of the totally integrated system, it does keep the required changes to existing designs at an absolute minimum.

A computer program was developed to determine the time-dependent power requirement of the AAP CSM.[57] The total requirement is determined whenever there is a load change. Mission average requirements are also computed.

Docking Dynamics

An analytical simulation of the docking dynamics of two rigid bodies that use the Apollo probe and drogue was developed using impulse-momentum techniques.[58] Although the simulation is inherently simple and includes several assumptions which lead to some loss of accuracy, agreement with more sophisticated analyses and tests is good. The value of this simulation is that it requires on the order of one hundredth of the computer time used by the more complex simulations, and thus permits development of trends in a variety of docking problems in a short time. Some 1,620 cases, with different initial contact conditions and on-off options on CSM axial thrust and attitude control, were run for the CSM to SWS axial docking problem. A principal conclusion of this study was that the use of axial thrust on the CSM offers significant improvement in the probability of successful capture, especially if the axial thrusters do not have to be shared with attitude control demands.

Environmental Control System Studies

An analysis of the humidity level in the AAP Cluster atmosphere was performed.[59] Initial buildup from a dry atmosphere to an equilibrium level

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(56) Analysis of the Parallel Operation of the AM and ATM EPS on the SWS, Memorandum for File, B. W. Moss, September 30, 1969.

(57) Power Profile Generator for the AAP CSM, Memorandum for File, L. L. Wang, September 9, 1969.

(58) Docking Dynamics Simulation for AAP, TM 69-1022-6, R. J. Ravera, July 24, 1969.

(59) Initial Humidity Buildup in the AAP Cluster, Memorandum for File, J. J. Sakolosky, July 25, 1969.

is primarily a function of crew metabolic rates and the water removal capability of the Environmental Control System (ECS). The specified minimum allowable dew point for the Cluster is 45° F. At a water generation rate of 6.6 lbs/day, which corresponds to three men at a metabolic rate of 500 Btu/hr each, an equilibrium dew point of 43° F is reached in three to four days. These results are in general agreement with similar results obtained by MSFC and at variance with those of McDonnell Douglas obtained with somewhat different assumptions. Additional study is planned by the Environmental Control Subpanel to further define the humidity condition for the Cluster.

The water management system of the AAP dependent CSM was examined.(60) The Apollo Block II CM water management system will be retained unmodified for the AAP/SWS program. Potable water will be supplied by the SM fuel cells for a period of two days after liftoff. If the fuel cells are operated past this point, the excess water generated will be dumped from the CM waste water dump. The water supply for the return to earth will be stored in a separate container which will be launched in either the CSM or the SWS.

Pressure Loss in the Saturn I Workshop

The extent and effects of Saturn I Wet Workshop leakage during the two-month quiescent interval between AAP missions were studied.(61) Atmosphere leakage at the maximum allowable rate would reduce the nominal 5.0 psia to about 2.5 psia in the OWS after the planned 60 day interval, and subsequently to about 0.5 psia at the end of 200 days. Equipment designed for operation at 5.0 psia in the OWS should, however, operate without deleterious effects at 2.5 psia.

The foregoing conditions prevail for either the wet or dry workshop configuration as long as the OWS is atmospherically isolated from the MDA/AM (as is the case for either the wet or dry workshop). The leakage rate during orbital storage from the MDA/AM, which is a separate pressure vessel, is much higher than from the OWS. At an estimated leak rate of 6.77 lbs/day, the MDA pressure can be expected to have decreased to about 2×10^{-6} psia (10^{-4} Torr) after 60 days orbital storage. Accordingly, equipment to be located in the MDA during orbital storage should be capable of withstanding extremely low pressure.

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(60) CM Water Management System Configuration For the AAP/SWS Program, Memorandum for File, J. J. Sakolosky, August 22, 1969.

(61) Pressure in the Saturn I Workshop During Orbital Storage, Memorandum for File, T. C. Tweedie, Jr., July 3, 1969.

Thermal System Studies

The development of thermal models of the AAP spacecraft and elements of their active thermal control systems was continued. This effort included special simplifying techniques for reducing model complexity and improving model usefulness and accuracy in computer simulations. Service Module radiator analysis led to a correction factor for the CINDA program (Chrysler Improved Numerical Differencing Analyzer) one way conduction model that is simple to apply and can substantially increase accuracy.(62) It was found that a simplified four-node model with this correction provided a very good approximation to results from a twenty-node model, including cases involving varying external solar heating.

A method was developed for computing the heat transferred and the gas and fluid exit temperatures for a condensing counter-flow heat exchanger.(63) This method was verified by application to the Command Module Suit Heat Exchanger and gave results that agree well with other reported analyses. Both CINDA and FORTRAN computer programs have been written and are operable.

The thermal coupling between the oxygen line and the supply and return water lines in a typical EVA umbilical was analyzed.(64) As the length of the umbilical is increased, the oxygen temperature exponentially approaches the average water temperature. For the planned 60 foot umbilical with an average water temperature of 46°F and an oxygen inlet temperature of -22°F, the oxygen outlet temperature will be 41°F.

Experience with operational thermal analysis computer programs was reported, including (1) a user's summary of CONFAC II, a general computer program for the determination of radiant-interchange configuration form factors, (2) notes regarding incident solar and diffuse infrared heat transfer

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(62) First Node Correction for Lumped Parameter Thermal Analysis of Tube Flow, Memorandum for File, G. M. Yanizeski, September 25, 1969.

(63) Command Module Suit Heat Exchanger Computation of Heat Loads and Water Condensation, Memorandum for File, D. P. Woodard, September 25, 1969.

(64) Thermal Coupling of Oxygen and Water Lines in an Insulated Umbilical - An Analysis, Memorandum for File, G. M. Yanizeski, September 30, 1969.

between a system of multi-surfaces, and (3) a discussion of the CINDA SCRPFA subroutine and its theoretical basis as used in radiative exchange between gray surfaces.[65, 66, 67]

Attitude Control Studies

In order to evaluate the propellant budget for the Workshop-Attitude-Control System (WACS), a mathematical model was developed for determining the impulse dispersions due to various system parameter uncertainties.[68] The model consisted of first and second order effects of the parameter uncertainties. Procedures were developed for numerical evaluation of sensitivity coefficients. The mean and variance of the impulse dispersion were calculated for independent Normal parameter uncertainties.

This model was used in estimating the WACS impulse requirements for attitude hold of the OWS/CSM configuration in the X-POP mode during the formerly planned 28 and 56 day AAP 1/2 and 2/3A missions. The results indicated that the total impulse requirement for attitude hold was 124,600 lb-sec including one standard deviation impulse dispersion of 6,340 lb-sec.

In continuation of previous studies, two methods were evaluated for implementing the oscillatory attitude profile about the X-POP attitude.[69] In the first method the deadband of the conventional position-plus-rate feedback control law was opened up such that the oscillatory attitude motion was contained within it. The second method involved generating a sinusoidal command attitude to approximate the oscillatory attitude. A tight position-plus-rate feedback control law was used to keep the actual attitude close to the commanded attitude.

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(65) CONFAC II Summary, Memorandum for File, J. E. Waldo, September 30, 1969.

(66) A Discussion of the CINDA SCRPFA Subroutine and Related Theory, Memorandum for File, G. M. Yanizeski, B. W. Lab, September 30, 1969.

(67) Thermal Radiation Networks, with Example of Lunar Ravine Heating, Memorandum for File, D. P. Woodard, September 25, 1969.

(68) Evaluation of RCS Impulse Dispersions in Attitude Hold Modes for AAP, TM-69-1022-9, B. D. Elrod, July 31, 1969.

(69) An Evaluation of Various Strategies for Implementing a Minimum-Fuel, Attitude-Hold Control Mode for the AAP Orbital Workshop, TM-69-1022-10, J. J. Fearnsides, September 30, 1969.

The evaluation concluded that the use of either of the methods resulted in a 40 to 50% reduction in both WACS propellant consumption and the number of thruster firings over that of the original design.

The effects of the oscillatory attitude motion on reduction of solar array effective area by both canting of the solar panels and shadowing by the OWS cylinder were evaluated.[70] These two effects combined reduce the solar array effective area by less than 2%.

The control margin of two ATM control moment gyros in the solar inertial attitude mode is directly related to the vehicle inertial properties. The inertial properties of the SWS were determined for two configuration modifications, the addition of an 8,000 lb vault for the protection of film from radiation, and the additional consumables required to provide a total manned mission duration of one year.[71,72] These additions, even if combined, are still within the capabilities of the two CMG's.

Stellar ATM

The ATM system has capability which may be useful for stellar astronomy. This potential, developed in conjunction with a second dry workshop, was described in a presentation to the Scientific and Technical Advisory Committee (STAC).[73]

System configuration and flight attitude alternatives were described in terms of their influence on acquisition pointing and attitude control. Expected fine pointing performance of the ATM gimbal system in the presence of crew motion disturbances is expected to be adequate, or require only minor improvement, for telescope systems with resolution of 0.1 arc seconds. The need for augmenting the system with a roll axis gimbal depends on the telescope requirements.

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(70) AAP Solar Array Effective Area Reduction From Proposed Attitude Control Maneuvers, Memorandum for File, J. W. Powers, September 24, 1969.

(71) The Effect of Addition of an Experimental Film Vault on Cluster Inertial Properties and CMG Control Capability, Memorandum for File, W. W. Hough, September 9, 1969.

(72) Consumables for One Year in Orbit with Second Saturn Workshop, Memorandum for File, W. W. Hough, September 26, 1969.

(73) STELLAR ATM Presentation to STAC, July 19-20, 1969, Memorandum for File, G. M. Anderson, July 25, 1969.

Bellcomm and Langley Research Center (LaRC) studies on fine pointing control of telescopes with an ATM type system (i.e., two degree-of-freedom hard gimbals) were reviewed.(74) It was concluded that, based on what is now known, no insurmountable control problem has been defined that precludes attaining a pointing stability of 0.01 arc sec rms. However, it was recognized that further analytical studies and simulations will be useful in uncovering potential problems.

Space Station Configuration

Configuration and flight attitude studies conducted in connection with the AAP Workshop have led to an approach for meeting the generalized pointing requirements of a space station.(75) The central idea is to employ a cylindrical geometry and utilize rigid body module rotations in conjunction with gimbal systems for pointing. By this means, all the pointing and rotational requirements which can be levied on a space station can be satisfied simultaneously. The preferred flight attitude for the system is with the cylindrical axis aligned with the orbital plane normal.

Communications

An analysis of the USB communication link between a CSM and the MSFN shows that all required real time modes (voice, telemetry, and ranging) can be supported by a CSM in earth orbit using an omnidirectional antenna and using its transponder in the low power mode (transmitter output of 125 milliwatts).(76) The MSFN station was assumed to be equipped with a 30 foot diameter antenna and an uncooled parametric amplifier. When using the CSM omnidirectional antennas for data dump modes, the high power transmitter mode would have to be used.

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(74) A Review of Bellcomm and LaRC Studies on Fine Pointing with an ATM Type System, Memorandum for File, J. Kranton, R. J. Ravera, P. G. Smith, September 23, 1969.

(75) Space Station Configuration and Flight Attitude, Memorandum for File, G. M. Anderson, August 1, 1969.

(76) Performance of Communications Link Between and MSFN (Uncooled 30') Antenna and an Apollo CSM in Earth Orbit, Memorandum for File, N. W. Schroeder, July 31, 1969.

An evaluation of methods of implementing a closed circuit television system on board the Saturn Workshop indicates that all the elements for such a system are available except the video cabling required to interface the television sensor and the monitors.(77) The portable color television camera carried to generate video signals for transmission to earth from the Orbital Assembly could be used to generate signals for a closed circuit television system. The monitors available include the black and white monitor supplied with the Apollo color camera and the monitors associated with the closed circuit television system of the ATM. If the ATM monitors are used, a device would have to be developed to derive synchronizing signals from the portable Apollo camera to drive the horizontal and vertical inputs required by the ATM television displays.

An analysis was made to determine the parameters for a communication terminal on the AAP workshop that would transmit and receive duplex voice, receive data at a one kbps rate from earth, and send telemetry to the earth at 72 kbps using the Intelsat IV as a relay satellite. Typical terminal parameters were found to be an 11 foot diameter antenna, a receiving system temperature of 1100°K and a transmitter power of approximately 25 watts.(78)

Design Reviews

During the quarter, Bellcomm personnel attended and provided technical support for the following program reviews:

Preliminary Requirements Reviews (PRR) on the AAP Command and Service Module and on the following experiments - the Pocket Mice Experiment (S071), the Vinegar Gnat Experiment (S072), the Bioassay of Body Fluids (M073), the Gravity Substitute Workbench Experiment (M507), the EVA and IVA Hardware Evaluation (M508);

Preliminary Design Reviews (PDR) on the Habitability Support System (HSS) and the Foot Controlled Maneuvering Unit (T020);

Critical Design Reviews (CDR) on the Hydrogen-alpha Telescopes and on the ATM Charger-Battery-Regulator Modules.

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(77) Provision of a Closed Circuit Television Capability On-Board the AAP Orbital Assembly, Memorandum for File, A.G. Weygand, September 15, 1969.

(78) AAP Terminal Requirements Using Intelsat IV for Communications Relay, Memorandum for File, R. K. Chen, September 24, 1969.

ADVANCED MANNED MISSIONS SYSTEMS ENGINEERING

Program Requirements

Integrated Space Program - Continued support was provided for the Office of Manned Space Flight effort to develop an integrated program plan. Draft documentation on objectives, accomplishments, flight hardware concepts and mission modes was prepared.

Mission Analysis

Integrated Space Program/Propulsion Stages - Studies aimed at sizing and determination of mission modes for the various program hardware elements were conducted. A propulsion module (LM/B PM) with a gross weight of 50,000 lbs was selected as one of these elements. Such a module could function both as a fourth stage on the Saturn V and as a lunar landing stage.(79) The propulsion module design was also evaluated as a system for launching unmanned planetary probes out of earth orbit.(80,81)

A study was conducted to compare chemical and nuclear stages for lunar and geosynchronous logistic support missions.(82) It was concluded that a chemical system comprised of the S-IVB plus the LM/B could perform the same function as the nuclear stage, but it requires more propellant-delivering space shuttle flights for the same logistic payload.

Integrated Space Program/Lunar Shuttle - A variety of modes for conducting shuttle operations between earth orbit and the lunar surface were analyzed

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(79) Rationale for Selection of a 50,000 Pound Propulsion Module in an Integrated Manned Space Flight Program, Memorandum for File, A. E. Marks, July 7, 1969.

(80) Application of the LM/B and Space Tug Propulsion Module to Unmanned Planetary Probes, Memorandum for File, A. E. Marks, July 22, 1969.

(81) Fully Reusable Automated Planetary Probe Injection System Using LM/B Propulsion Modules, Memorandum for File, A. E. Marks, September 18, 1969.

(82) A Chemical Alternative to the Nuclear Shuttle, Memorandum for File, E. M. Grenning, August 21, 1969.

from the point of view of vehicle performance.[83] These modes included (1) a reuseable earth orbit/lunar orbit shuttle utilizing lunar orbit rendezvous, with alternatives of returning the LM to earth orbit, expending the LM, or basing the LM in lunar orbit; (2) a direct lander; and (3) lunar refueling, either on the lunar surface or in lunar orbit. In addition, comparisons were made between the performance of nuclear and chemcial interorbital shuttles and also between the advantages of highly elliptic and low altitude circular rendezvous orbits.

Integrated Space Program/Manned Planetary Missions - A study to examine configuration and mission concepts for a program of manned planetary flights in the 1980's was completed.[84] The emphasis was placed on Mars, but missions to Venus were also examined. Conjunction class missions were selected to exploit the required long duration system capability by spending several hundred days at Mars on each flight. The exploration strategy was to begin with a manned orbital mission with surface sample collection using sterile probes. Successive missions would be manned landers with the capability for at least two surface expeditions per mission. Each mission required three intermediate Saturn V launches and nuclear shuttle transportation from low to high earth orbit. Total assembled weight prior to transplanetary injection was about 700,000 lbs, including one nuclear stage for both earth departure and Mars capture. A LM/B propulsion stage boosted the manned module out of Mars orbit and into an earth orbit for a quarantine period before astronaut return to the earth surface.

Role of Man - When the primary goal of a space mission does not require man's presence in space, tradeoffs must be made between alternatives which include fully manned, man-tended, remotely controlled, and fully automated systems. Possible advantages of having man's capabilities availablc on a space mission were outlined, but it was concluded that hard decisions on when to actually employ these capabilities must be postponed until better cost data on all the alternatives becomes available.[85]

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(83) Comparison of Several Lunar Shuttle Modes, Memorandum for File, H. S. London, September 29, 1969.

(84) Integrated Space Program: Manned Planetary Missions for the 1980's, Memorandum for File, W. B. Thompson, August 6, 1969.

(85) Criteria for Using Man in Space, TM-69-1011-5, G. T. Orrok, August 11, 1969.

Crew Size Sensitivity - The relationships between crew size and performance were investigated.[86] Crews consisting of one man to seven and more were analyzed in order to determine their capabilities compared with those of a reference six-man crew. Uncertainties in space station design, work loads, and degrees of automation preclude confident optimization of crew sizes, but tends and significant factors were pointed out.

Orbital Observations - The effects of orbital parameters (specifically, the altitude and inclination for circular orbits) and instrument field of view on the frequency of sighting fixed targets on the earth's surface from orbit were analyzed.[87] It was noted that the 50°, 270 nm orbit frequently used for space station studies has a repeating ground track; this makes some sites permanently inaccessible. To improve accessibility, the inclination can be maintained if the altitude is changed. For an instrument with a viewing half angle of 30°, altitudes outside the range 270±25 nm are required to view any site at U.S. latitudes at least once every five days.

Configuration Studies

Space Shuttle - Studies of launch modes and configurations for the space shuttle, a reusable space transportation vehicle that will operate between earth and low earth orbit, were initiated. In one option, the second stage of a fully reusable two stage shuttle is replaced with a high performance cryogenic stage that is not designed to reenter the atmosphere.[88] In this mode much larger payloads can be delivered to earth orbit than with the fully reusable shuttle. The cryogenic stage has the potential for replacing the nuclear shuttle if it is designed for reuse in space.

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(86) Crew Size Sensitivity Study of a Multidisciplinary Earth Orbital Space Station, TM-69-1015-6, S. L. Penn, September 19, 1969.

(87) Low Altitude Orbits for Earth-Looking Experiments, TM-69-1011-6, S. Shapiro, September 23, 1969.

(88) Space Shuttle Launch of Large Payloads and In-Space Stages, Memorandum for File, H.S. London, D. Macchia, September 25, 1969.

One possible payload for the space shuttle is a propulsion stage designed for initial start in earth orbit. The shuttle could carry empty stages or stage components in cases where the fully fueled and assembled stage exceeds the shuttle capacity. The nuclear shuttle or its chemical equivalent could be launched in this manner and then fueled in earth orbit after assembly.(89)

Consideration of the large reduction in payload that would result if the weight of the two stage space shuttle structure and subsystems were to grow during development led to a preliminary study of a contingency development plan.(90) If the reusable orbiter (second stage) is developed ahead of the reusable booster (first stage), the orbiter could be flown with a Saturn V first stage (S-IC) for some period of time until the reusable booster is operational. This approach would permit the booster stage to be developed according to the requirements of the known characteristics of the orbiter stage.

Computer Configurations - Four computer configurations (uniprocessor, multiprocessor, twin uniprocessor and dedicated uniprocessor) were compared for use on a space station.(91) Included in the criteria for comparison were computational capability, lead time, risk, program manageability, programmability, adaptability, expandability, reliability, maintainability, weight, power and volume. Each configuration has some characteristic that makes it outstanding in terms of some single criterion, but the multiprocessor appears better than the others in terms of computational capability, expandability, reliability and maintainability.

Parachute Recovery - A survey of the reliability, weight, volume and state of development of gliding parachute recovery systems was performed.(92)

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(89) This was subsequently reported in Conceptual Design and Performance of Large Propulsion Stages Dry Launched within a 50K Space Shuttle Payload Compartment, Memorandum for File, A. S. Kiersarsky, M. H. Skeer, October 1, 1969.

(90) Space Shuttle Development with Built-In Contingency, Memorandum for File, D. E. Cassidy, September 30, 1969.

(91) Evaluation of Computer Configurations for a Space Station, Memorandum for File, B. W. Kim, September 15, 1969.

(92) Gliding Parachutes for Land Recovery of Space Vehicles, Memorandum for File, W. H. Eilertson, September 8, 1969.

Gliding performance required for a pinpoint landing is a function of reentry guidance and control system accuracy and the altitude of main chute deployment. For a given landing accuracy, increasing the deployment altitude reduces the required gliding performance. For the Apollo semi-ballistic command module shape, a gliding parachute recovery system with an L/D of 3.5 deployed at 20,000 ft would provide pinpoint landing capability. Several of the gliding parachute systems currently under development have the necessary gliding performance to provide semi-ballistic reentry vehicles with pinpoint landing capability.

Astronaut Life Support - A conceptual design of a vomit removal apparatus that could be retrofitted to an EVA pressure suit was developed.(93) Two versions of the basic design were considered: an open loop version in which the vomit is vented into space, and a closed loop version in which the vomit is collected in a trap. Both types required the use of only one hand for their operation.

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(93) Vomit Removal Apparatus for an EVA Pressure Suit: A Design Concept, Memorandum for File, M. A. Robinson, July 29, 1969.

MISSION OPERATIONS STUDIES

A number of analyses were made of alternate MSFN configurations and launch windows to help NASA establish an efficient and economic configuration of the MSFN. The results of these analyses were transmitted to the Director of Mission Operations.

Observations were made of the performance of the voice communication with the Apollo spacecraft during the Apollo 11 prelaunch tests and mission.[94,95,96] In general, the voice communications within the KSC network were good, but some anomalies were observed in the spacecraft/ground communication links.

A memorandum was issued on the performance of the voice communication system during the Apollo 10 launch.[97] It originally appeared that some spacecraft voice messages were not received, but this was found to be not true although some words at the beginning of messages were lost.

A potential future need for a low capacity communications system to support a lunar seismic network was recognized, and optimum detectors for such a system were studied.[98] It was found that if there is not a priori statistical knowledge of phase noise, a random step detector is the preferred choice, but if the phase noise is known to exhibit linear drift characteristics, a more efficient detector can be specified.

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(94) This was subsequently reported in Observations of the KSC Voice Communications System During the Apollo 11 CDDT, Memorandum for File, L.A. Ferrara, H. Kraus, October 8, 1969.

(95) This was subsequently reported in Voice System Performance Observations Made at LCC 39/KSC During Launch of Apollo 11, July 15-16, 1969, Memorandum for File, L.A. Ferrara, October 8, 1969.

(96) Voice System Performance Observations Made at CDSC/KSC During Launch of Apollo 11, July 15-16, 1969, Memorandum for File, J.J. Hibbert, B.F. O'Brien, July 28, 1969.

(97) This was subsequently reported in Voice Communication Analysis During the Apollo 10 Launch, Memorandum for File, L.A. Ferrara, October 8, 1969.

(98) Optimization of a Very-Low Capacity Channel Using a Multi-Tone Frequency Shift Keyed Detector - Part II, TM-69-2034-6, L. Schuchman, August 11, 1969.

SPECIAL TASK ENGINEERING STUDIES

Manned Space Flight Experiments Program Studies

Task Order No. 34

Several studies relevant to the design and conduct of space experiments in various science and applications disciplines have been carried out.

Space Physics - Studies concerning a high energy physics and cosmic ray facility in space continued. New approaches for the design of critical instrumentation elements, such as hardware for the detection, activation and recording of particle tracks, were proposed.[99] For more accurate recording of particle paths, it was suggested that spatial location could be improved by a factor of at least three by a simple extension of present techniques, and a factor of ten or more by new, and yet untested, solid state techniques. It was recommended that detection and activation using gas Cerenkov counters be replaced by simple, fast-logic plastic-scintillator systems.

X-Ray Astronomy - Analysis revealed that daytime atmospheric X-ray fluorescence will affect 20-35 Å X-ray astronomy only in low earth orbit when the visibility of weak sources is desired.[100] The effects of this fluorescence, caused by photoionization of atmospheric oxygen and nitrogen, can be considerably reduced by operating in orbits above 300 nm. At 225 nm, during solar quiet, the atmospheric fluorescence is approximately that of the lowest background X-ray flux measured in this wavelength region.

Earth Sensing - A report was prepared which itemized the geological indicators of mineral deposits identifiable by remote sensing and suggested how these may serve as guides for subsequent exploration.[101] The practical economics of reconnaissance by remote sensors was considered. Specific physical and mass properties measurable by sensors were enumerated. Current surface and aircraft exploration techniques were reviewed and instrumentation pertinent to satellite exploration described. The NASA earth resources aircraft

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(99) An Approach Toward the Implementation of a High Energy Physics and Cosmic Ray Facility in Space, TM-69-1015-4, L. Kaufmann, July 25, 1969.

(100) Daytime Atmospheric X-ray Fluorescence and Its Effect on X-ray Astronomy, Memorandum for File, F. F. Tomblin, September 5, 1969.

(101) Remote Sensing for Mineral Deposits, TM-69-1015-5, W. L. Smith, August 11, 1969.

and test site programs were summarized. Comments and recommendations were offered relevant to population demands on finite resources and the role of man in remote sensing for mineral deposits.

The application of remote sensing to the exploration for phosphate rock was examined.[102] An ideal system for reconnaissance includes satellite imaging plus an aircraft subsystem using radar and aeroradioactivity equipment. Phosphate rock was selected as the first of several ores to be reviewed inasmuch as (1) it is of worldwide economic importance, and (2) it is in the class of ores for which some applicable techniques of remote sensing have already proven useful. A similar system was recommended as a possible means for locating economically important placer gold deposits in offshore bars and beaches.[103]

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(102) Applications of Remote Sensing to Exploration for Phosphate Rock, Memorandum for File, W. L. Smith, July 18, 1969.

(103) Applications of Remote Sensing to Exploration for Offshore Gold, Memorandum for File, W. L. Smith, September 23, 1969.

SPECIAL TASK ENGINEERING STUDIES

Analysis of Haze Effects on Martian Surface Imagery

Task Order No. 35

Earlier work on a model for the Martian atmosphere haze based on Mariner IV data has been extended.[104] The accuracy of models used for atmospheric scattering and surface photometry was examined and it was determined that, although refinements could be made, the quality of the Mariner IV data did not warrant further modifications. The most significant result of the haze model was that it explained both the brightness above the limb and the low surface contrast seen by Mariner IV. The model has been used to predict atmospheric brightness for Mars under illumination and viewing conditions different from Mariner IV and more appropriate to Mariners '69 and '71. The current interpretation of Mariner '69 data is that the amount of haze present in the Mars atmosphere is remarkably less than was apparently seen by Mariner IV. The implications of this for the haze model are being examined.

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(104) A Model of the Martian Haze, TR-69-235-1, E.N. Shipley, July 14, 1969.

Scientific Studies

Planetary Atmospheres - A three dimensional time-dependent model of general atmospheric circulation on Venus was developed.(105) Since the rotation of Venus is slow but finite, equator-to-pole and day-to-night temperature differences can be expected to be of comparable magnitude. Thus, two dimensional models of the steady state circulation between the subsolar and antisolar points do not provide an adequate description of the circulation. Results of the three-dimensional model computation predict the mean atmospheric motions to be essentially meridional, except in a narrow belt near the equator, where, at a latitude of about 10°, the direction changes abruptly to zonal.

A further study, taking directly into account the spherical geometry appropriate for the problem, confirmed the general conclusions of the earlier model.(106) It revealed in detail the departure from symmetry of the atmospheric flow pattern, which rotates about the polar axis of Venus with the period of the Venusian day, and displayed the sensitivity of the flow pattern to the ratio of equator-to-pole and day-to-night temperature difference.

The dependence of atmospheric circulation on various types of heating was investigated using a linear model.(107) It was shown that a small temperature perturbation caused by the presence of an absorbing layer at an altitude of ten kilometers or less is capable of maintaining an isothermal layer below it. Substantial circulation can exist without destroying this isothermal region.

The artificial production of an oxygen rich atmosphere on Mars and the moon was investigated to determine the energy requirements.(108) Assuming

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(105) General Circulation in the Atmosphere of Venus Driven by Polar and Diurnal Variations of Surface Temperature, TR-69-103-7-2, I. O. Bohachevsky, T. T. J. Yeh, July 10, 1969.

(106) General Circulation in the Atmosphere of Venus Driven by Differential Heating of the Surface, Paper submitted for publication in the "Journal of Atmospheric Sciences," T. T. J. Yeh.

(107) A Parametric Study of Atmospheric Circulation With a Linear Model, TM-69-1014-6, I. O. Bohachevsky, August 25, 1969.

(108) The Artificial Production of a Respirable Atmosphere on the Moon and Mars, Memorandum for File, W. R. Sill, July 22, 1969.

as a production mechanism the heating and decomposition of silicate rocks, approximately 10^{32} ergs would be required to create an earth-type atmosphere. The amount of rock required as raw material corresponds to the top ten meters on the moon and the top three meters on Mars.

Radio Interferometer Experiment - A preliminary analysis of data from 11.1 cm microwave interferometer observations of Venus near inferior conjunction (Spring, 1969) has been reported.[109,110] The equator-to-pole surface temperature difference is estimated to be less than 12°K, contrary to earlier investigations by other experimenters who noted significant polar cooling. A comparably small variation of brightness temperature with longitude at the equator was also observed.

Instrumentation - Upper atmosphere density can be measured directly with a free molecule density gage mounted on a space vehicle. Typically the gage has a single orifice for gas entry on the upstream side. A multi-orificed gage design was described that can reduce dependence on angle of attack, which is one source of error in reducing the data to determine the density.[111]

Satellite Tracking - Doppler data derived from earth-based tracking of a satellite orbiting a planet can be used to determine the satellite orbit and elements of the planet gravitational field. When two satellites are in orbit about the planet at the same time, the accuracy of the desired results may be improved if data from a satellite-to-satellite Doppler link are included. Under the particular assumptions employed, it was found that for equal tracking times estimated accuracies of satellite orbit and gravitational field parameters improved two to

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(109) The Surface Temperature Distribution on Venus, Paper presented at the American Astronomical Society Meeting, Albany, New York, August 12, 1969, A. C. E. Sinclair, W. A. Gale, M. Liwshitz (Bellcomm) and J.P. Basart, D. Buhl (National Radio Astronomy Observatory).

(110) Interferometric Determination of the Temperature Distribution and Atmospheric Profiles on Venus, Paper presented at the IAU-URSI Symposium on Planetary Atmospheres and Surfaces, Woods Hole, Massachusetts, August 11-15, 1969, A. C. E. Sinclair, W. A. Gale, M. Liwshitz (Bellcomm) and J.P. Basart, D. Buhl (National Radio Astronomy Observatory).

(111) Modification of a Free Molecule Density Gage, Memorandum for File, R. N. Kostoff, July 9, 1969.

four orders of magnitude when the satellite-to-satellite data was used in conjunction with earth-based data, compared to earth-based data alone.[112]

Solar Flare Sensing - A study of a concept for an automatic spaceborne system that will scan the sun for flares was completed.[113] The sensor is a camera tube which uses an array of 1000 x 1000 reverse-biased electrically isolated silicon diodes. Its output is sampled and digitized every ten seconds. A digital computer uses the digitized information in algorithms which group co-linearly adjacent points into horizontal line segments and then connect concurrently adjacent line segments to define an object. The object is tracked from frame to frame and its characteristics are used to categorize it. The study was directed toward flare detection, but modification of the algorithms may permit detection of other phenomena such as sunspots and plages. Also, the sensor has a broad spectral range that might allow observation of these phenomena in the X-ray range.

Ultracentrifuge - An analysis was performed to ascertain whether the productivity of an ultracentrifuge could be improved by using the weightless environment of an orbiting space station to eliminate the requirements for rotor suspension, thereby allowing large increases in rotor radius. The functional relationship between productivity and rotor radius for sedimentation through both homogeneous and linear density gradient solvents was determined.[114] The analysis showed that both separation time and sample size increased almost linearly with rotor radius so that the productivity remained practically constant. Therefore, no first order advantage would be gained by placing an ultracentrifuge in orbit.

Technological Studies

Nuclear Stage - The performance of a nuclear powered stage (10,000 lb thrust) of a size that could be used in conjunction with a Titan IIIM booster to launch unmanned satellites was analyzed for a suborbital start mission mode.[115]

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(112) Determination of Planet Gravitational Field Using Two Satellites, Memorandum for File, C. L. Greer, September 15, 1969.

(113) Automatic Spaceborne Solar Flare Detection, TM-69-1031-2, R. K. Agarwal, July 25, 1969.

(114) Ultracentrifuges in Earth Orbit, Memorandum for File, L. D. Sortland, July 1, 1969.

(115) Sub-Orbital Start Performance of a Small Nuclear Stage, Memorandum for File, D. J. Osias, July 8, 1969.

It was found that the payload capability could be increased by 40% over that provided using an orbital start mode for the nuclear stage.

The weight of a nuclear powered stage that could be assembled in low earth orbit from modules launched by the space shuttle was calculated for a 1981 80-day stopover Mars mission.[116] This assembly mode typically necessitates placing 350,000 lbs more weight (an increase of 20% over the total original weight) in low earth orbit than would be required if the nuclear stage were first assembled on the ground and then launched by a Saturn V.

On-Orbit Satellite Servicing - Satellite servicing, the maintenance, repair and upgrading of unmanned satellites in orbit, was studied as a method of prolonging and improving their operational status. Potential servicing operations were identified and their impact on satellite design was investigated together with an assessment of the factors which must be considered to make these operations practicable.[117] The Nimbus weather satellite was studied in some detail to determine how its design might be affected by requirements for on-orbit servicing.[118] Emphasis was directed toward the problem of accessibility to satellite components. Alternative configurations that would improve the serviceability of this satellite were suggested.

Characteristic velocity requirements were derived for non-coplanar transfer between a 250 nm circular orbit and other circular orbits.[119] The results were plotted so as to be convenient for the study of satellite servicing, shuttling, and other orbital missions.

Space Station Stabilization - The attitude motion of space stations rotating about a symmetry axis was studied. It was shown that for spin rates greater than about 1/40 rpm such stations can passively maintain a stable attitude

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(116) Modularized Nuclear Stage Performance for 1981 Mars 80-Day Stopover Mission, Memorandum for File, D. J. Osias, September 9, 1969.

(117) Potential Satellite Servicing Operations and the Impact of Servicing on Satellite Design, Memorandum for File, M. H. Skeer, July 31, 1969.

(118) Effects of In-Orbit Servicing on Nimbus Configuration, Memorandum for File, A. S. Kiersarsky, July 18, 1969.

(119) Characteristic Velocity Requirements for Intraorbital Phasing and Interorbital Transfer Missions, Memorandum for File, H. B. Bosch, July 14, 1969.

relative to an earth-pointing reference frame only if the rotation axis is placed normal to the orbit plane.[120]

Data Processing Planning - Support is being provided to the NASA Preliminary Computer Study. Representatives are participating on all five teams formed for this study. Informal presentations were made of (a) data concerning the size of the current NASA flight operations in terms of dollars, people and computers and (b) the level of flight control activities in MSF that would result from one particular schedule of missions.

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(120) A Study of the Passive Attitude Motion of Three Generic Types of Space Station Configuration, Memorandum for File, H. B. Bosch, September 24, 1969.

ENGINEERING SUPPORT

Computing Facility

During the quarter, the transition of the operation of the UNIVAC 1108 computer from reliance on the EXEC II batch programming system to reliance on the EXEC 8 multi-programming system has been essentially completed. During August and September, the total amount of work performed by EXEC 8 was about 99% of the total work performed by the computer facility.

The major problem with EXEC 8 during this transition phase has been its instability. There are implementation errors in the EXEC 8 system itself, and when this erroneous code is executed, the machine stops. An intensive effort has been made to find and fix these errors. The "stop" rate has been reduced by these efforts, but further improvement is needed.

During the period from July 1 to September 30, NASA Headquarters usage of the UNIVAC 1108 computer was 10.8 hours under EXEC II and 28,699 charge units under EXEC 8.

The computing facility continues to function as back-up to the 1108 computer complex at MSC during the Apollo missions. Prior to the Apollo 11 mission, the MSC programs were run at Bellcomm to verify the operation of this back-up capability.

ADMINISTRATIVE

Cost Reduction Program

Bellcomm's Semi-annual Cost Reduction Report to NASA was submitted in July showing an annual savings of $23,500 for the period ending June 30, 1969.

LIST OF REPORTS AND MEMORANDA

(List in Order of Report Date)

This index includes technical reports and memoranda reported during this period covering particular technical studies.

The memoranda were intended for internal use. Thus, they do not necessarily represent the considered judgment of Bellcomm which is reflected in the published Bellcomm Technical Reports.

TITLE	DATE
Ultracentrifuges in Earth Orbit, Memorandum for File, L. D. Sortland	July 1, 1969
Pressure in the Saturn I Workshop During Orbital Storage, Memorandum for File, T. C. Tweedie, Jr.	July 3, 1969
Rationale for Selection of a 50,000 Pound Propulsion Module in an Integrated Manned Space Flight Program, Memorandum for File, A. E. Marks	July 7, 1969
Sub-Orbital Start Performance of a Small Nuclear Stage, Memorandum for File, D. J. Osias	July 8, 1969
Modification of a Free Molecule Density Gage, Memorandum for File, R. N. Kostoff	July 9, 1969
Spectrum Analyses of Apollo 10 S-IVB First and Second Burn, Memorandum for File, A. T. Ackerman, L. A. Ferrara.	July 9, 1969
General Circulation in the Atmosphere of Venus Driven by Polar and Diurnal Variations of Surface Temperature, TR-69-103-7-2, I. O. Bohachevsky, T. T. J. Yeh	July 10, 1969
UNIVAC 1108 FORTRAN V Version of MIT Conic Subroutines Used in Apollo Guidance Computer, Memorandum for File, C. O. Guffee, J. C. Gurasich	July 10, 1969

TITLE	DATE
A Model of the Martian Haze, TR-69-235-1, E. N. Shipley	July 14, 1969
A Modified Perigee and Apogee Velocity Expression to Reduce Radius Errors Caused by the Earth's Asphericity, TM-69-1025-1, P. H. Whipple	July 14, 1969
Characteristic Velocity Requirements for Intraorbital Phasing and Interorbital Transfer Missions, Memorandum for File, H. B. Bosch	July 14, 1969
Further Results of Tradeoffs Between Walking and the Use of Mobility Aids During Lunar Surface EVA, Memorandum for File, P. Benjamin	July 14, 1969
LEP Post Traverse Location of Scientific Sites Using CSM Photography, Memorandum for File, D. M. Duty	July 14, 1969
Flight Test of the LM Landing Point Designator, Memorandum for File, A. C. Merritt	July 17, 1969
Applications of Remote Sensing to Exploration for Phosphate Rock, Memorandum for File, W. L. Smith	July 18, 1969
Effects of In-Orbit Servicing on Nimbus Configuration, Memorandum for File, A. S. Kiersarsky	July 18, 1969
Updated S-II Longitudinal Structural Model, Memorandum for File, H. E. Stephens	July 18, 1969
Predictive Entry Guidance for Apollo. Part 1: Design and Performance, MM-9-4162-2, J. A. Stiles, G. Bamesberger (Bell Telephone Laboratories)	July 21, 1969
Predictive Entry Guidance for Apollo. Part 2: Structure and Operation, MM-9-4162-3, J. A. Stiles, G. Bamesberger (Bell Telephone Laboratories)	July 21, 1969
Application of the LM/B and Space Tug Propulsion Module to Unmanned Planetary Probes, Memorandum for File, A. E. Marks	July 22, 1969

TITLE	DATE
The Artificial Production of a Respirable Atmosphere on the Moon and Mars, Memorandum for File, W. R. Sill	July 22, 1969
Required Transmitter Power for Ground Wave Radio Propagation Beyond the Lunar Horizon in the 100 kHz to 10 MHz Frequency Band, Memorandum for File, K. H. Schmid	July 23, 1969
Statistical Analysis of Project Pyro Liquid Propellant Explosion Data, TM-69-1033-3, P. Gunther, G. R. Andersen	July 23, 1969
ALEM Checkout at KSC, Memorandum for File, C. H. Eley, III	July 24, 1969
Axisymmetric Shells, TM-69-2031-3, S. Kaufman	July 24, 1969
Docking Dynamics Simulation for AAP, TM-69-1022-6, R. J. Ravera	July 24, 1969
An Approach Toward the Implementation of a High Energy Physics and Cosmic Ray Facility in Space, TM-69-1015-4, L. Kaufman	July 25, 1969
Automatic Spaceborne Solar Flare Detection, TM-69-1031-2, R. K. Agarwal	July 25, 1969
Initial Humidity Buildup in the AAP Cluster, Memorandum for File, J. J. Sakolosky	July 25, 1969
STELLAR ATM Presentation to STAC, July 19-20, 1969, Memorandum for File, G. M. Anderson	July 25, 1969
Voice System Performance Observations Made at CDSC/KSC During Launch of Apollo 11, July 15-16, 1969, Memorandum for File, J. J. Hibbert, B. F. O'Brien	July 28, 1969
Electrical Power System for AAP Dry Workshop, Memorandum for File, B. W. Moss	July 29, 1969

TITLE	DATE
Vomit Removal Apparatus for an EVA Pressure Suit: A Design Concept, Memorandum for File, M. A. Robinson	July 29, 1969
A Study of Methods for Determining the Location and Magnitude of Lunar Mass Concentrations, Memorandum for File, M. Lybanon, R. M. Scott	July 30, 1969
Addition of "Mascons" in BCMTAP and a Preliminary Analysis of their Effects on Orbit Determination, Memorandum for File, J. T. Findlay	July 31, 1969
Eigenvalues and Eigenvectors of Symmetric Matrices, Memorandum for File, J. S. Vandergraft	July 31, 1969
Evaluation of RCS Impulse Dispersions in Attitude Hold Modes for AAP, TM-69-1022-9, B. D. Elrod	July 31, 1969
Performance of Communications Link Between an MSFN (Uncooled 30') Antenna and an Apollo CSM in Earth Orbit, Memorandum for File, N. W. Schroeder	July 31, 1969
Potential Satellite Servicing Operations and the Impact of Servicing on Satellite Design, Memorandum for File, M. H. Skeer	July 31, 1969
Characteristics of the Ten Lunar Exploration Sites, Memorandum for File, F. El-Baz	August 1, 1969
Space Station Configuration and Flight Attitude, Memorandum for File, G. M. Anderson	August 1, 1969
GLEP Site Selection Subgroup, Fourth Meeting, June 17, 1969, Memorandum for File, N. W. Hinners	August 4, 1969
Integrated Space Program: Manned Planetary Missions for the 1980's, Memorandum for File, W. B. Thompson	August 6, 1969
Performance at Lunar Range of a Unified S-Band PM Communication Link Between an MSFN Station With an 85 ft. Antenna and a LM Using an Omni Antenna, Memorandum for File, N. W. Schroeder	August 6, 1969

TITLE	DATE
Recent Developments in Space Vehicle Turnaround Operations for Lunar Missions, Memorandum for File, C. H. Eley, III	August 6, 1969
Criteria for Using Man in Space, TM-69-1011-5, G. T. Orrok	August 11, 1969
EVA Metabolic Capacity Required for LEP Life Support Systems, Memorandum for File, T. A. Bottomley	August 11, 1969
Optimization of a Very-Low Capacity Channel Using a Multi-Tone Frequency Shift Keyed Detector - Part II, TM-69-2034-6, L. Schuchman	August 11, 1969
Optimum and Suboptimum Demodulators for FM Signals With Multiple Subcarriers, TM-69-2034-7, W. D. Wynn	August 11, 1969
Preliminary Thoughts on Cryogenic Servicing of the 16-Day CSM, Memorandum for File, G. J. McPherson, Jr.	August 11, 1969
Remote Sensing for Mineral Deposits, TM-69-1015-5, W. L. Smith	August 11, 1969
Interferometric Determination of the Temperature Distribution and Atmospheric Profiles on Venus, Paper presented at the IAU-URSI Symposium on Planetary Atmospheres and Surfaces, Woods Hole, Massachusetts, A. C. E. Sinclair, W.A. Gale, M. Liwshitz (Bellcomm) and J. P. Basart, D. Buhl (National Radio Astronomy Observatory)	August 11-15, 1969
The Surface Temperature Distribution on Venus, Paper presented at the American Astronomical Society Meeting, Albany, New York, A. C. E. Sinclair, W.A. Gale, M. Liwshitz (Bellcomm) and J. P. Basart, D. Buhl (National Radio Astronomy Observatory)	August 12, 1969

TITLE	DATE
Determination of Dynamic Loads and Response of a Space Vehicle Using Flight Data, TM-69-2031-4, S. N. Hou,	August 14, 1969
Mission H1 Landing Site Visibility by Goldstone, Parkes and Jodrell Bank, Memorandum for File, R. A. Bass	August 14, 1969
Differences Between Proposed Apollo Sites: 1.. Synthesis "Journal of Geophysical Research," Volume 74, No. 17, A. F. H. Goetz (Bellcomm) and H. H. Kieffer, T. B. McCord, B. V. Murray (California Institute of Technology)	August 15, 1969
Differences Between Proposed Apollo Sites: 3. Far Infrared Emissivity Evidence, "Journal of Geophysical Research," Volume 74, No. 17, A. F. H. Goetz (Bellcomm), L. A. Soderblom (California Institute of Technology)	August 15, 1969
Minutes of the August 12-14 Meeting of an Ad Hoc Working Group on the Science Objectives of Apollo Missions 12-20, Memorandum for File, F. El-Baz, D. B. James	August 18, 1969
Review of Portable Life Support System Capabilities for LEP, Memorandum for File, T. A. Bottomley	August 19, 1969
A Chemical Alternative to the Nuclear Shuttle, Memorandum for File, E. M. Grenning	August 21, 1969
ΔV Cost of Updating the Landing Site During the LM Descent Braking Phase, Memorandum for File, F. LaPiana, P. A. Whitlock	August 21, 1969
CM Water Management System Configuration for the AAP/SWS Program, Memorandum for File, J. J. Sakolosky	August 22, 1969
A Parametric Study of Atmospheric Circulation With a Linear Model, TM-69-1014-6, I. O. Bohachevsky	August 25, 1969
Engineering Implications of Preliminary Scientific Traverses for the Apollo J Missions, Memorandum for File, P. F. Sennewald	August 25, 1969

TITLE	DATE
An Interpretation of Photographic Data showing S-IVB Cryogen Releases during Apollos 8 and 9, Memorandum for File, A. C. Buffalano	August 29, 1969
A Star Finder and Identifier for Use on the Surface of the Moon, Memorandum for File, D. A. Corey	September 2, 1969
Daytime Atmospheric X-ray Fluorescence and Its Effect on X-ray Astronomy, Memorandum for File, F. F. Tomblin	September 5, 1969
Definition of Energy Costs for Lunar Surface EVA, Memorandum for File, T. A. Bottomley	September 8, 1969
Gliding Parachutes for Land Recovery of Space Vehicles Memorandum for File, W. H. Eilertson	September 8, 1969
Modularized Nuclear Stage Performance for 1981 Mars 80-Day Stopover Mission, Memorandum for File, D. J. Osias	September 9, 1969
Power Profile Generator for the AAP CSM, Memorandum for File, L. L. Wang	September 9, 1969
The Effect of Addition of an Experimental Film Vault on Cluster Inertial Properties and CMG Control Capability, Memorandum for File, W. W. Hough	September 9, 1969
A Computer Method for the Determination of Rational Functions, TM-69-1033-4, S. Y. Lee	September 10, 1969
Some GLEP Recommendations on Lunar Exploration Sites, Memorandum for File, F. El-Baz	September 11, 1969
Determination of Planet Gravitational Field Using Two Satellites, Memorandum for File, C. L. Greer	September 15, 1969
Evaluation of Computer Configurations for a Space Station, Memorandum for File, B. W. Kim	September 15, 1969
Provision of a Closed Circuit Television Capability On-Board the AAP Orbital Assembly, Memorandum for File, A. G. Weygand	September 15, 1969

TITLE	DATE
Lunar Atmospheric Contamination Due to an Apollo Landing, TM-69-2015-5, G. K. Chang	September 16, 1969
Use of the Landing Point Designator to Land the Lunar Module in a Circular Target Area, Memorandum for File, K. P. Klaasen	September 16, 1969
CSM LH_2 Quantity Redline Negative Margin on the Apollo 12 Mission, Memorandum for File, G. J. McPherson, Jr.	September 18, 1969
Fully Reusable Automated Planetary Probe Injection System Using LM/B Propulsion Modules, Memorandum for File, A. E. Marks	September 18, 1969
A Possible VHF Backup Communications System Between Extravehicular Astronauts on the Lunar Surface and the Earth, Memorandum for File, R. L. Selden	September 19, 1969
Crew Size Sensitivity Study of a Multi-Disciplinary Earth Orbital Space Station, TM-69-1015-6, S. L. Penn	September 19, 1969
Method for Estimating the Electrical Conductivity of the Lunar Interior, TR-69-103-7-4, W. R. Sill, J. L. Blank	September 22, 1969
Reporting Procedures for Detailed Objectives, Memorandum for File, H. F. Connor	September 22, 1969
A Review of Bellcomm and LaRC Studies on Fine Pointing with an ATM Type System, Memorandum for File, J. Kranton, R. J. Ravera, P. G. Smith	September 23, 1969
Applications of Remote Sensing to Exploration for Offshore Gold, Memorandum for File, W. L. Smith	September 23, 1969
Low Altitude Orbits for Earth-Looking Experiments, TM-69-1011-6, S. Shapiro	September 23, 1969
A Method for Determining Minimum ΔV Two Impulse Transfer Trajectories Between Arbitrary State Vectors and Its Application to Three Impulse LOI Optimization, Memorandum for File, R. A. Bass, E. A. McGinness	September 24, 1969

TITLE	DATE
A Study of the Passive Attitude Motion of Three Generic Types of Space Station Configuration, Memorandum for File, H. B. Bosch	September 24, 1969
AAP Solar Array Effective Area Reduction From Proposed Attitude Control Maneuvers, Memorandum for File, J.W. Powers	September 24, 1969
AAP Terminal Requirements Using Intelsat IV for Communications Relay, Memorandum for File, R. K. Chen	September 24, 1969
APO Briefing September 24, 1969, Precision of Consumables Estimates For Apollo, Memorandum for File, S. S. Fineblum	September 24, 1969
Command Module Suit Heat Exchanger Computation of Heat Loads and Water Condensation, Memorandum for File, D. P. Woodard	September 25, 1969
First Node Correction for Lumped Parameter Thermal Analysis of Tube Flow, Memorandum for File, G. M. Yanizeski	September 25, 1969
Space Shuttle Launch of Large Payloads and In-Space Stages, Memorandum for File, H.S. London, D. Macchia	September 25, 1969
Thermal Radiation Networks, with Example of Lunar Ravine Heating, Memorandum for File, D. P. Woodard	September 25, 1969
Consumables for One Year in Orbit with Second Saturn Workshop, Memorandum for File, W. W. Hough	September 26, 1969
Entry Monitoring System Study, TR-69-310-1 I. Bogner, G. Duncan, C. H. Eley, III, D. S. Lopez, S. B. Watson	September 26, 1969
Review of Model Synthesis Techniques and a New Approach, TM-69-2031-5, S. N. Hou	September 26, 1969
Comparison of Several Lunar Shuttle Modes, Memorandum for File, H.S. London	September 29, 1969

TITLE	DATE
Stars and Planets Visible in the LM AOT During the Lunar Stay Time of the Apollo 12 Mission, Memorandum for File, T. L. Yang	September 29, 1969
A Discussion of the CINDA SCRPFA Subroutine and Related Theory, Memorandum for File, G. M. Yanizeski, B. W. Lab	September 30, 1969
An Analysis of Apollo 10 Tracking Data Utilizing the POLAR Version of the Osculating Lunar Elements Program, TM-69-2014-9, M. V. Bullock, A. J. Ferrari	September 30, 1969
An Evaluation of Various Strategies for Implementing a Minimum-Fuel, Attitude-Hold Control Mode for the AAP Orbital Workshop, TM-69-1022-10, J. J. Fearnsides	September 30, 1969
Analysis of the Parallel Operation of the AM and ATM EPS on the SWS, Memorandum for File, B. W. Moss	September 30, 1969
CONFAC II Summary, Memorandum for File, J. E. Waldo	September 30, 1969
Propagation Characteristics of Apollo 8 L. P. O. Solutions Obtained from the Osculating Lunar Elements Program, Memorandum for File, M. V. Bullock, A. J. Ferrari	September 30, 1969
Representation of Osculating Orbital Elements by Analytic Functions, Memorandum for File, M. Lybanon, R. M. Scott	September 30, 1969
Space Shuttle Development with Built-In Contingency Memorandum for File, D. E. Cassidy	September 30, 1969
Spatial Orientation of a CSM Relative to a Sun-Oriented SWS during a Typical AAP Rendezvous, Memorandum for File, C. O. Guffee, R. C. Purkey	September 30, 1969
Thermal Coupling of Oxygen and Water Lines in an Insulated Umbilical - An Analysis, Memorandum for File, G. M. Yanizeski	September 30, 1969

TITLE	DATE
TSAP - A Target Site Analysis Program, Memorandum for File, D. P. Nash	September 30, 1969
Water and Cryogens in Space: Some Physical Considerations, Memorandum for File, A. C. Buffalano	September 30, 1969
Conceptual Design and Performance of Large Propulsion Stages Dry Launched Within a 50K Space Shuttle Payload Compartment, Memorandum for File, A. S. Kiersarsky, M. H. Skeer	October 1, 1969
Observations of the KSC Voice Communications System During the Apollo 11 CDDT, Memorandum for File, L. A. Ferrara, H. Kraus	October 8, 1969
Voice Communication Analysis During the Apollo 10 Launch, Memorandum for File, L. A. Ferrara	October 8, 1969
Voice System Performance Observations Made at LCC 39/KSC During Launch of Apollo 11, July 15-16, 1969, Memorandum for File, L. A. Ferrara	October 8, 1969
Color Differentiation by Computer Image Processing, Paper to be published in "Photographic Science and Engineering Journal", A. F. H. Goetz (Bellcomm) and F. C. Billingsley, J. N. Lindsley (Jet Propulsion Laboratory)	
General Circulation in the Atmosphere of Venus Driven by Differential Heating of the Surface, Paper submitted for publication in the "Journal of Atmospheric Sciences" T. T. J. Yeh	

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R. W. May - RV-1
J. T. McClanahan - MOR
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J. L. Mitchell - SG
G. E. Mueller - M
R. V. Murad - MAT
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H. E. Newell - AA
O. W. Nicks - SD
W. T. O'Bryant - MAL
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R. A. Petrone- MA
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N. Rafel - MR
O. E. Reynolds - SB
W. P. Risso - KD-3
E. D. Rosen - KDM-MA
M. Savage - MLT
L. R. Scherer - MAL
W. C. Schneider - ML
A. D. Schnyer - MTV
J. R. Shaw - MT
J. B. Skaggs - MAP
J. E. Smart - W
J. D. Stevenson - MO
W. E. Stoney - MA
F. J. Sullivan - RE
A. O. Tischler - RP
G. M. Truszynski - T
J. H. Turnock - MO
S. P. Vinograd - MMR
M. G. Waugh - MTP
G. C. White - MAR
M. E. White - MRD
J. W. Wild - MTE
W. H. Woodward - RN

Ames Research Center

D. Dennis - M(OART)

Kennedy Space Center

F. J. Bailey - SAK
S. P. Beddingfield - AP-SYS
W. T. Clearman - AP-SYS
K. H. Debus - CD
R. C. Hock - AA
E. R. Mathews - AP
R. O. Middleton - AP
T. W. Morgan - AA

Manned Spacecraft Center

A. A. Bishop - KM
A. Cohen - PF
M. E. Dell - KA
H. W. Dotts - KS
M. A. Faget - EA
H. E. Gartrell - KF
R. R. Gilruth - AA
W. N. Hess - TA
W. R. Kelly - PP7
C. C. Kraft - FA
G. M. Low - AA
A. Liccardi - RASPO/Bethpage
O. E. Maynard - PD
J. A. McDivitt - PA
O. G. Morris - PE
R. O. Piland - TF
J. R. Sevier - PD
D. K. Slayton - CA
R. F. Thompson - KA
G. S. Trimble - AB
J. M. West - AE

Marshall Space Flight Center

L. F. Belew - PM-AA-MGR
L. B. Bell - PM-SAT-E
P. Dunlap - PM-AA-GE
R. E. Godfrey - PM-SAT-MGR
R. L. Goldston - PM-PR-M
G. B. Hardy - PM-AA-EI
W. A. Huff - PM-SAT-E
L. B. James - PM-DIR
J. V. Klima - PD-AS
G. F. McDonough - S&E-CSE-A
W. A. Mrazek - PD-DIR
L. G. Richard - S&E-DIR
M. W. Shettles - PM-SAT-P
S. C. Smith - PM-SAT-G
W. vonBraun - DIR
H. K. Weidner - S&E-DIR
F. L. Williams - PD-DIR
F. S. Wojtalik - S&E-ASTR-S